Title of Investigation:

Advanced Micropattern Sensor Development

Principal Investigator:

Keith Jahoda (Code 662)

Other In-house Members of the Team:

Phil Deines-Jones (Code 662)

External Collaborators:

Kevin Black (Forbin LLC)

Initiation Year:

FY 2004

Aggregate Amount of Funding Authorized in FY 2003 and Earlier Years:

$0

FY 2004 Authorized Funding:

$55,000 and 0.2 Full-Time Equivalent (FTE)

Actual or Expected Expenditure of FY 2004 Funding:

In-house: $55,000

Status of Investigation at End of FY 2004:

Our focus on developing low-cost and robust detectors has shifted to in-house techniques rather than purchasing commercially made devices.

Expected Completion Date:

Completed 2004

Purpose of Investigation:

The Goddard Space Flight Center's Laboratory for High Energy Astrophysics (LHEA) is involved in several detector-development efforts. Specifically motivating this proposal are the instrument named Lobster-ISS All-Sky Monitor and efforts to develop photoelectric X-ray polarimetry. Lobster-ISS is a European Space Agency-led effort to which LHEA would supply the detectors. Polarimetry can distinguish, among competing models, the geometry of X-ray emission regions; photoelectric polarimetry promises substantial increases in sensitivity. Imaging gas detectors are required for this measurement.

Initial LHEA involvement in imaging gas detectors was based on the in-house production of Gas Electron Multiplier (GEM) detectors. The traditional GEM consisted of a perforated dielectric sheet with metal on both sides. With the application of a few hundred volts between the top and bottom surfaces, electrons that drift into the high field region in the holes multiplied, allowing readout by a variety of means. We initially produced GEM detectors by laser machining of thin plastic or acrylic substrates with patterned metal electrodes on either side. While we were able to produce detectors in this way, the process was not stable and required too much time and labor. Our investigation proposed to build on the work of a group at the University of Chicago, which, in collaboration with 3M, had successfully fabricated GEM detectors of about 1 inch in diameter using an industrial roll-to-roll process. Our hope was to capture this industrial process to allow our detector development effort to focus on detector design rather than sensor production.

FY 2004 Accomplishments:

During FY 2004, we had two cycles of sensor production at 3M. The first attempt, which produced square detectors of 10 cm on a side, was disappointing and we were unable to produce a usable quantity. Detailed examination of the profile of each microscopic hole in the devices revealed, however, that more dielectric material remained in the hole than for the original University of Chicago devices. After consultation with 3M engineers, we were able to identify the process steps necessary to produce the same geometry for the individual holes as the University of Chicago devices. A second sensor-production run was completed; this time duplicating the University of Chicago hole geometries with a larger overall active area. Our experience with these detectors was mixed. We were able to achieve modest gain, although the breakdown voltages were lower than predicted based on the Chicago experience. The detectors required several hours to reach their equilibrium performance, presumably due to charging effects. This is likely to be a complication for applications in low-Earth orbit, where it is often necessary to cycle detectors once per orbit due to passage through the South Atlantic Anomaly. Some gas mixtures worked better than others; J. Martoff (Temple University) reported satisfactory performance in a carbon disulfide detector. We have suspicions about the uniformity of the metal adhesion over the entire detector, and remain unconvinced that the process is understood well by the manufacturer and that high-quality devices can be easily produced for our application.

During this process, we became aware of the availability of finely patterned etched or electro-formed mesh, and began experimenting again with making detectors in-house out of parallel pieces of fine pitch mesh. (This led directly to the FY 2005 Director's Discretionary Fund (DDF) proposal, entitled "Low-Outgassing Robust Micropattern Detectors," proposed by Principal Investigator P. Deines-Jones.)

While it remains likely that detectors could be produced via industrial roll-to-roll processing, we have discovered at least two complications. First, 3M requires at least 6 weeks after the receipt of an order to deliver product. The order has to compete with 3M's lucrative business of making storage media for modern high-capacity disk drives. As a result, turn-around times can be longer. Second, and most important, making the process work for a particular application requires that the process engineers have an interest and personal stake in the process. If we work as "process engineers" to construct detectors out of electro-formed mesh re-inserts, we can substantially reduce the time required to make detectors. To the extent that working with metallized plastic substrates and developing suspicions about the adhesion of the metal/plastic interfaces led us to a promising plastic-free implementation, this effort was successful. To the extent that we are not buying "off-the-shelf" detectors, it was not.

During FY2004, no patents were prepared, and no professional publications or presentations were made concerning this work.

Planned Future Work:

Future work will concentrate on the design and manufacture of detectors based on electro-formed or etched metal foils and is supported by an FY 2005 DDF grant to the co-investigator on this proposal, P. Deines-Jones.

Summary:

The production of imaging gas detectors with resolution of between 80 and 500 microns remains an enabling technology for missions of interest to the Goddard LHEA. These missions range from polarimetry, which requires true pixel imaging, to all-sky monitors, which require simultaneous coordinate determination in two dimensions, to X-ray timing, which requires large area. Developing processes for building large area gas detectors, with the possibility of imaging readout, is therefore of great interest. We have determined that at present, the best path toward achieving such detectors appears to be through in-house assembly of commercially procured mesh. This investigation contributed to our current understanding of this approach.